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## **Trip Report**

### **LHC IRQ Collaboration US-IT-HXTU Installation-Operation**

June 12 – August 3, 2000  
CERN, Geneva Switzerland

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August 25, 2000

### **Summary**

This was the second stage in what we planned for the operation of the “United States Inner Triplet Heat eXchanger Test Unit (US-IT-HXTU) (see previous trip report May 9, 2000). The US-IT-HXTU first campaign was essential to characterize the LHC Interaction Region quadrupole cooling system. The conduction of operations within its full capacity range could define potential changes of the final design of critical components before starting the IR quadrupoles series production. In addition, the test bench was used to build the control strategy for the LHC operation. The full-scale model operated in collaboration with the cryogenics for accelerators group (ACR) at CERN.

The scope of the present report is to specify how the main steps of the project were handled. Our charge included the instrumentation and electrical connection set-ups, commissioning, control and supervision developments as well as the operation process and data measurement. The first month was dedicated to completing the installation, the second to the operation. Some results have been analyzed and the conclusion regarding the validation of the LHC IR Inner Triplet cooling system can be drawn from the results.

The present report tries to be conservative and emphasizes problems met while installing and operating the US-IT-HXTU. Despite the so-called problems, it turned out that the run was very successful regarding the difficulty of the adaptation of an American made assembly in an European coded-stamped country. This is the first hardware built in the US to be operated at CERN for the LHC accelerator, in the framework of the US LHC collaboration.



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### **LHC IRQ Collaboration US-IT-HXTU Installation-Operation**

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# **1 FINAL INSTALLATION OF THE US-IT-HXTU**

The first stage of our trip was to check the follow-up of the installation started in February. During the previous stay, the supporting system was designed, manufactured and installed, the installation of the feed box, turnaround and four modules were completed, the survey for the alignment of the US-IT-HXTU was performed in addition to several coordination tasks. CERN safety requirements prompted some adaptations that were respected so far. The electrical needs for the powering and the data acquisition and control were defined and initialized. Some instrumentation devices were mounted in April.

Since April, the welding of interconnection bellows has been performed as well as the connection between the feed-box and the SM18 cryogenic supply system. The heat exchanger tubes were first welded, regarding the process that we studied in March. On the basis of the April discussions, extra supports were installed between the heat exchanger tube and its outer shell. They prevent the deflection of the heat exchanger tube and assure a smoother flow of the saturated He II. The study of the heat exchanger tube deflections is reported in document EST-SU/AS2. Finally, all lines were welded to their respective interconnection bellows, in accordance with standard CERN safety practices. Welding zones appeared to be very well. Yet, the CERN assembly team stressed the problem of the pipe alignment before welding. They had to move pipes and the thermal shield system in order to be able to connect pipes. For some interconnections, pipe fixations had to be removed. Consequently, interconnection bellows have to accept a non-negligible offset. We measured and reported to the Technical Inspection & Safety (TIS) division each bellows misalignment. Squirm protectors are used in order to limit the misalignment and buckling risk during the cool-down and the pressure test.

Later on, the turnaround inner assembly turns out to be moved when we pumped on the internal saturated He II circuit during the leak check. Therefore, we decided to weld 6 pads on the heat exchanger outer shell turnaround bellows, then we installed three threaded bars capable of accommodating the contraction. More details concerning the closing of the vacuum vessel bellows are emphasized in the chapter 3.3.

## **2 INSTRUMENTATION AND ELECTRICAL DEVICES**

### **2.1 CALIBRATION OF CONTROLLED DEVICES**

Three control valves (Circle Seal control) were installed on the top of the feed-box. They are main devices for the control of the cool-down and the conduction of the operation. They needed to be mechanically recalibrated before use. Since these devices were not CERN standard devices, we met some difficulties in zeroing them. Nevertheless, using adequate notices and valves drawings we were able to recalibrate them before we cooled down the test bench.

The pressure controller (TPG300) also needed to be recalibrated. Since the two vacuum indicators were not CERN standard, we needed to contact a company in Geneva (Balzers). We used these conversion data to read the insulation vacuum, and implemented them in the DAQ program.

The parameters of the three control valves had to be mastered and fine tuned for a better operation. A strict approach was observed before starting cooling down.

### **2.2 THERMOMETERS MOUNTING**

Some of the thermometers assembled on the thermal shield in April, were damaged while welding interconnection parts. We tried to replace some of them, but we lost 1 out of 5 thermometers and another one provided a 3 wires thermal measurement. The ACR/

instrumentation section helped us to remount one thermometer on the turnaround side (Nicolas Vauthier, Sebastien Pelletier). Each single thermometer resistance was checked using a device that we fabricated in April. Resistances were compared to the measurements performed at Fermilab, checking any malfunctioning of any sensors due to the shipment.

### **2.3 ELECTRICAL CONNECTIONS AND DAQ**

An important issue was to finalize the installation of the electrical powering panel which was ordered in April. On our arrival, it appeared that the 1kW electrical supply was not installed yet. Therefore, we stressed the installation so that the powering was made available on the 6<sup>th</sup> of July. A special connection for tetra-phase was installed for the use of the molecular turbo pump. The Uninterrupted Power Supply (UPS) was connected for most of the devices. Fortunately, this delay did not slow down the commissioning since this last requested less power than we borrowed from the SM18 general network. Since the electrical net and UPS system were made available during the commissioning step, we checked that the switching to the final system did not disturb our preliminary measurements. Jean-Mathieu Bernal was responsible with the follow-up of the electrical installation.

For safety reasons, we were asked to ground each module ; the action was provided the 30<sup>th</sup> of June. The cable routing frames were installed at the beginning of our stay. The two electrical racks were installed in the SM18 hall on the 22<sup>nd</sup> of June.

Then, we hooked up rack devices to module connectors through cables that were prepared out a specification issued in March with Michel Condemine. Once we checked each channel read-out, we could hook up the system to the PLC and DAQ and control system.

PCVIEW is the software used for the supervision interface with the PLC. The 4<sup>th</sup> of July, Jean-Baptiste Bart and an expert from Paris set the program in order to prepare the run. The 87 signals from the US-IT-HXTU were accessible via the prepared synoptic and supervision panels. The 6<sup>th</sup> of July, the access to data through the web was made available. Therefore, we moved the computer system to the SM18 control room. Important signals from the cryogenics plant were also accessible via our supervision system so that we can operate the US-IT-HXTU with respect to the other users of the SM18 cryogenic supply. Jean-Baptiste Bart made available an automatic alarm message sent by email and to our cell phone.

The 19<sup>th</sup> of June we installed a roughing pump and the turbo molecular pump with Gerarld Bochaton and Christian Berthelier

## **3 COMMISSIONING AT ROOM TEMPERATURE**

### **3.1 LEAK CHECK - STEP 1**

In April, we defined a procedure to perform the leak check. The 16<sup>th</sup> of June, we performed the first leak check on the global internal helium circuit. The interconnection welding area were accessible, i.e. the vacuum vessel bellows were not in position yet. We pressurized the inner circuit with helium gas up to 1.1 bar pressure. A portable helium detector was used to detect the helium presence around each of the interconnection bellows. No leak was noticed.

### **3.2 PRESSURE TEST – STEP 2**

The procedure of the pressure test was also written in April. Since all directives concerning the connection of the feed-box to the SM18 cryogenic supply system were not respected, we had to readapt the test scenario. Actually, the feed-box pipes were already welded to the CERN cryogenics valves, preventing the insulation of the internal volume from the SM18 cryogenic supply system, during the pressure test. Fortunately, CERN cryogenic valve box sizes were

compatible with the requested pressure to be used for our pressure test. Several meetings with TIS inspector (Claude Margaroli) and Raphael Vuillermet ensured adequate parameters for the pressure test.

Once we established the process and the hydraulic circuit for the pressure test, we had to order, collect and calibrate all requested equipment: helium battery, valves, pressure indicator, manoregulator and chart recorder. Most of these devices were borrowed from other experiments.

Prior to the test, bellows were equipped with their squirm protectors. Interconnection shield bridges were not in position since we wanted to witness the behavior of each bellows.

Since the maximum allowable working pressure is 4 bar (Joule-Thomson heat exchanger), we first performed a pressure test up to 5 bar. This test was performed in collaboration with Raphael Vuillermet the 21<sup>st</sup> of June after the working hours (safety reasons). Notable expansions of bellows in the axial direction were observed and plotted vs. the applied pressure. The expansion of bellows at the interconnection right next to the feed-box was particularly large (55 mm for an absolute pressure of 3.5 bar). This large expansion is due to missing fixed points in the feed-box assembly. No stop support prevents the displacement and rotation of the supply and return pipes linked to the first module pipes. Construction drawings permitted to estimate the risk of bending pipes. Regarding the position of supports inside of the feed-box and the fact that bellows fatigue remains reasonable for at least 100 thermal cycles, no danger was foreseen and we decided to carry out the test. Moreover, up to 12 mm of tilt in the radial direction was measured for bellows on the feed-box and turnaround side, inducing misalignment problems.

Since we were not pleased with this first pressure test result, we considered the real working pressure. Finally, we run the pressure test at 2.5 bar relative, which is 1.5 time larger than the normal working pressure. A similar study of bellows expansion and offset was carried over. Following this test, the certificate for approbation was given the 3<sup>rd</sup> of July. This certificate underlines the satisfying criteria and constitutes the basis for accepting the safety requirements for the operation of the US-IT-HXTU at a pressure bellow 2 bar. A study of the measured expansion was added to the TIS certificate that Claude Margaroli signed.

### **3.3 CLOSING THE VACUUM VESSEL**

Ten layers of MLI were wrapped around bellows and pipes in order to reduce static heat loads from the thermal shield to helium supply lines. Then, the interconnection bridges were installed. Their fixations to module thermal shields had to be modified in order to cope with the bellows and pipes misalignment. In a next step, 10-layer blankets of MLI were wrapped around the interconnection bridge. Then, we closed the vacuum vessels with their respective bellows.

Unfortunately, bellows needed to be stretched by 1 inch at each interconnection. Actually, the final distances in-between each vacuum vessel was larger then the expected one. Modules had to be located with a larger interconnection space so that we can weld the heat exchanger tube, because of incompatibility of the heat exchanger tube lengths between the feed-box, modules and turnaround. The connection of the heat exchanger tube does not include any flexible parts or bellows that would help. Hence, bellows, including the vacuum vessels one, had to be stretched compared to their initial length.

The proposed clamps designed for closing the vacuum vessel turned out to be inappropriate to the extra force induced by the stretching. Thus, we had to order and installed larger clamps from a firm in Switzerland.

### **3.4 PUMPING DOWN**

Once the vacuum vessel volume was closed, we started pumping down the insulation volume with the rouging pump (30<sup>th</sup> of June). The evolution of the insulation vacuum was previously

estimated from measurements performed at Fermilab. Thus, we could check the MLI outgassing rate. Thanks to these previous measurements, the pumping time-constant could be estimated. Therefore, we took the advantage of the weekend to pump this large volume. On Monday 3<sup>rd</sup> of July we reached  $4 \cdot 10^{-2}$  mbar, and the molecular turbo-pump was switched on.

The helium internal circuit was purged four times in order to be sure that we would not send impure gas to the SM18 return helium gas system.

Moreover, these purges permitted to clean the Joule-Thomson heat exchanger from air that could condense into water then freeze during the cool-down, meaning that we would lower the performance of the Joule-Thomson heat exchanger. After the purge, we pumped on the global circuit down to  $10^{-6}$  mbar.

The pressure safety valve installed on the subatmospheric volume was connected to the balloon return circuit, in order to prevent any air from entering the helium circuit.

### **3.5 FINAL LEAK CHECK – STEP 3**

After the pressure test was performed, and once we assured that the vessel was properly closed and pumped down to a correct vacuum ( $\sim 10^{-3}$  mbar), the third stage consisted of leak checking the internal volume. The final leak check test was performed the 4<sup>th</sup> of July, since the helium background was low enough. The helium signal measured was  $10^{-8}$  mbar/l.s if the pressurization was 120 mbar. Some more leak checks were performed for a pressure up to 240 mbar. In any case the signal was lower than  $10^{-7}$  mbar/l.s, meaning that no leak was identified.

After the commissioning at room temperature was performed, the pressure safety valves were installed with the adequate procedure. The rupture disk was mounted. We connected the subatmospheric pressure safety valve relief to the SM18 low-pressure gas system.

## **4 COMMISSIONING AT COLD TEMPERATURE**

### **4.1 COOL-DOWN**

The supporting systems were set free from their positioning blocs in order to ensure any axial displacements of the vacuum vessels due to cool-down conditions.

We were able to start cooling our test bench the 10<sup>th</sup> of July. Beside, liquid helium supply valve capacity was very large, and requested to be manually reduce to 10% of its opening during the first cool-down. It took 2 days to stabilize the dummy cold mass to 4 K.

The thermal shield cooled by the helium vapor stabilized its temperature at 100 K. This final temperature was still really high compared to the estimated value, due to high thermal contact impedance between the shield and its cooling pipes. Furthermore, the control valve for the cooling of the thermal shield, appeared to be under-sized, therefore the helium mass-flow was reduced causing a poor heat transfer to cool the thermal shield. This sizing of the valve resulted also in an increase of the pressure within the phase separator, therefore it was difficult to supply liquid helium to the dummy cold mass. First, Bruno Vuillerme suggested to remove the physical limitation of the valve. When we studied the control valve design, we saw that a specific part was limiting the hydraulic section. This part could be accessible and removed if we considered to warm-up the test bench. Fortunately, the manual control of the valve cone stroke also permitted to increase the flow. We pulled the valve cone up to its maximum limit. Consequently, the pressure in the phase separator decreased to 1.1 bar and the transfer of liquid helium permitted to cool-down the dummy cold mass properly. Several steps in the stabilization of the system were possible thanks to the control of the PLC. We took a few days to set the parameters for the PID, limits and interlocks (in collaboration with Enrique Blanco).

During the cool-down we noticed the influence of the flow restriction located between the heat exchanger and its outer pipe. These composite plates were added in order to simulate the real inner triplet case, where they are used to balance to cool-down flow. Actually, helium would first flow in the space between the heat exchanger tube and its outer shell rather than in the magnet lamination (higher hydraulic resistance). In our case we don't have magnets so the main worry was to note a large thermal gradient (100 K) between the magnet simulator pipes and the heat exchanger outer tubes, parallel and connected by stiff pipes. The thermal differential contraction for the magnet simulator pipes were stressing the connection pipes welding. Nevertheless after few hours, the thermal gradient was lowered to acceptable values.

Once the dummy cold mass temperatures were as low as 6 K, a valve was closed and maintained liquid helium inside the dummy cold mass. As a matter of fact, the 12<sup>th</sup> of July we learned that the cold compressor unit (CCU1) from Air Liquid was malfunctioning. Fortunately, a second CCU is installed in the SM18 cryogenics hall. This Linde CCU2, was rapidly connected to our system. The efficiency of the cryogenics team work (Bruno Vuillerme, Lionel Herblin) permitted us to use the optimal pumping capacity by the 14<sup>th</sup> of July, therefore to cool-down from 4.2 to 1.9 K. We started pumping in the heat exchanger internal pipe, transferring the helium enthalpy from the stagnant pressurized helium to the flowing saturated superfluid helium which is pumped to the cold compressor down to 16 mbar. After several hour, we evacuated the heat from the bath which filled up with pressurized superfluid helium at 1.9 K. Conditions were optimal on Friday 14<sup>th</sup> of July.

We were asked to inform Sigrid Knoops of our helium consumption since CERN has to face a crisis with liquid helium suppliers. Special care was taken to lower the consumption to its minimum.

Before we left for the weekend we ensured that the PID parameters were optimized in order to permit an automatic and safe regulation of the HXTU. Stabilization of the system was possible the 17<sup>th</sup> of July.

## **4.2 ZEROING**

This was a compelling reason to check the sensors resistance at cold temperature. The helium level transducer located inside of the feed-box accumulator as well as its duplicate were damaged. We were able to save one of them, which is essential for the proper use of the test bench.

Calibration curves were established for most of the devices. A mass-flowmeter is installed just before the Joule-Thomson valve. We performed the calibration of the turbine mass flowmeter for various heat loads, i.e. various mass-flow. We cross-checked results with a calibration performed on a similar device. Its accuracy is as poor as 20%. Some more correlations were established using the Joule-Thomson opening, the read-out of the turbine mass flowmeter, the mass flowmeter installed at the cold-compressor side and the liquid helium quantity coming from the phase separator. These correlations help with the conduction of the operation.

The temperatures are measured with Cernox resistors calibrated at Fermilab and powered with  $10^{-6}$  amperes. Conditioners were mounted by CERN. The raw temperature displays turned out to be very variable. The accuracy of thermometers is not optimal in the temperature range observed. The temperature distribution along the heat exchanger tube is essential in order to determine the heat exchanger performances. Thus, we performed a zeroing of the temperature, by recording the distribution of the thermometers read-out for a set of given saturated temperatures. In fact, we controlled the saturated helium temperature, then we opened the Joule-Thomson valve in order to wet the whole length of the heat exchanger tube. No electrical power is added in the pressurized superfluid helium bath. The temperature of the saturated helium is equal to the pressurized heliu

if we say that the static heat load to the system is null. Out of these measurements Enrique Blanco built a file used for the data analysis.

## 5 MEASUREMENTS

Once we assured that the commissioning and the zeroing provided us with necessary and trustable measurements, we could work out the performance of the LHC IRQ cooling system, on the 17<sup>th</sup> of July. The cool-down provided us the requested helium conditions at 1.9 K (pressurized and saturated). Resistive heaters in the pressurized superfluid helium are used to simulate various distribution of heat loads at 1.9 K.

In order to have clean measurements we had to operate when we were the only users of the CCU. We used the measurement of the mass-flowmeter installed on the warm side of the CCU, therefore we could not share the 1.8 K pumping. Even if no more than 6 g/s was needed for both quadrupole and dipole, their cooling process disturbed our measurement. Moreover, we could not run in parallel because their quench periods were random and planned with difficulty, hence the disturbance in the pressure stability was obvious.

The main idea of the measurement is to reach steady-state for a given heat load condition. The read-out of the temperature distribution permits to estimate the thermal performance of the heat exchanger. The measurement of the thermo-hydraulic performances permits to measure the transient behavior during the cool-down and to scale the control strategy for the LHC.

For the functioning of the HXTU, the liquid helium is taken out of the phase separator at 4.2 K, 1 bar. It passes through a liquid/gas counter-current Joule-Thomson heat exchanger where it gets cooled down to 2.6 K, then it undergoes a Joule-Thomson expansion to saturation pressure. The 1.8 K saturated He II is transported via the supply tube to the far end of the heat exchanger. When flowing back to the accumulator, it vaporizes as it takes the heat from the pressurized helium volumes. During the measurement, we estimated the vapor fraction after the Joule-Thomson valve opening, as well as the wetted area of the heat exchanger tube, equal to 18% and 25%, respectively.

The helium level in the accumulator and the thermometers located right next to the accumulator are used as indicator for the steady state conditions. For each measurement, the principal is to fix the Joule-Thomson valve opening for a constant mass-flow and to increase the module electrical power in order to simulate magnets dynamic heat loads at 1.9K. Once the Joule-Thomson valve opening is fixed and the heat load applied, all temperatures vary with a transient behavior for 2 to 5 hours before they stabilize.

The input parameters are the JT valve opening, the saturated temperature and the heat load distributions. The output is the temperature distribution for the steady state. The goal is to stabilize temperatures within a 2 mK range.

The controlled strategy aimed at minimizing the mass-flow to get a small overflow in the accumulator (phase 1). This strategy is representative of the LHC and permits a parameterization of the cooling process to be used. Results are cross-checked by adding electrical power to the accumulator and work with a constant liquid level in the accumulator (phase 2).

The data analysis went on in parallel in order to conduct proper measurements. A first set of measurements was performed with a given 16 mbar saturated pressure. It was impossible to use the full capacity of the CCU (18 g/s at 10 mbar) to absorb the highest heat loads while keeping a temperature as low as 1.8 K on the saturated side, because of an unexpected pressure drop in the Joule-Thomson heat exchanger side. More analyses were developed at Fermilab to show the contribution of the CERN cryogenic valves and the Joule-Thomson heat exchanger pressure

drops. Tom Peterson helped us by email in order to calculate the estimated pressure drop seen by the Joule-Thomson heat exchanger itself. Still, this unexpected pressure drop did not bring any real disturbance to the test, as time did not permit any extra measurements. After we noticed the unexpected pressure drop, we decided to operate with a larger saturated pressure.

Large sets of data consider 18, 19 and 21 mbar saturated pressure. Displays of temperatures were recorded then analyzed at Fermilab. We also checked the influence of an unbalanced electrical power distribution. The distribution difference of temperature was significant. Following this observation, we ran the best guess for the nominal conditions of the LHC. The ultimate conditions were measured with a factor 1.5 times the nominal conditions. Actually, we tried to use a larger power, but the heater power supplies were unstable, because there were limited in voltage instead of being limited in current. After several tries to apply power higher than 400 W, we noticed that CCU mass flow was as well unstable, therefore we decreased to 315 W. We also experienced some stops of the CCU. In order to limit this kind of incident in the middle of the night, we preferred to run the ultimate at 16.3 g/s instead of 18 g/s.

Interesting phenomenon were witnessed for high mass-flow, like the wave effects: undular behavior of liquid phase of superfluid helium flowing within the heat exchanger tube.

The liquid phase velocity of the saturated He II was also measured for given mass-flow meters: 10-15 minutes for 30 m of tube.

In summary, 36 points of measurement permitted us to characterize the performance of the LHC IRQ cooling scheme, for various heat loads in the explored temperature range, representative of the LHC conditions. The nominal condition was analyzed as well as an ultimate condition (1.5 time the nominal heat load). The influence of the heat load distribution was also tested. The results are now available on the web, which is our tool to communicate with Rob van Weelderen at CERN and the US-IT-HXTU team.

Later on, Rob performed an additional set of measurement at 32 mbar. Alain Bezaguet performed a set of measurement with lower mass flow for 18 mbar and 21 mbar. Alain also provided a great support while we were testing the main conditions.

## **6 PLANNING**

Several weekly meetings permitted to organize the test program. Every Monday morning a status of the magnet tests took place in the control room. Every 2 weeks a meeting for the SM18 activity coordination enabled us to stress the need of a correct schedule and to adapt our test program. During our stay, 2 meetings dealing with the ACR group activities took place. For most of these meeting we were requested to present the planning and the issue of the experiment. The last day we were asked to present our results to the head of the LHC division (Philippe Lebrun) and the group of people who worked with us.

Concerning the schedule, we had many worries. Since we had to share the full capacity of the cold compressor, we had to coordinate our activities with the magnet team (LHC/MMS). Since their tests were considered high priority regarding the deadline for the String 2 test, we had no other choice than working with their spare time, meaning at night and during the weekend. This was a real constraint to our measurement, quantitatively and consequently qualitatively. We made an agreement with the magnet people so that they could find their magnets at nominal thermal conditions, when they arrived by 8-9 in the morning in order not to be disturbed to start their magnetic tests. For these reasons the cryogenic team (Antonio Tovar-Gonzalez) adapted the program for the cool-down of magnets so that we can initiate the process at the end of our night measurements.

Nevertheless the idea was first to assure the pertinence of our measurement then to measure as many conditions as possible to be analyzed back to Fermilab. Almost very single hour of the free use of the cold compressor full capacity was used for our measurement. In two weeks, we had to run many conditions. As a matter of fact the week following our departure the magnet test benches were free and our colleagues from CERN had the full opportunity to measure other conditions.

The 2<sup>nd</sup> of August we organized the visit of Bernard Rousset from CEA Grenoble with 2 of his students. Bernard, Rob van Weelderen and Alain Bezaguet used to work on a similar project back in 1993 (Cryoloop). His advice was really appreciated.

## **7 RESULTS AND STATUS**

With respect to these results, no improvement to the final LHC IRQ cooling design is necessary. The measurements with the nominal and the ultimate LHC conditions, confirm our predictions obtained with the small-scale heat exchanger (SSHX).

The heat exchanger tube is estimated to be wetted on 20-25% of its area. The temperature differences between saturated and pressurized superfluid helium are less than 35 mK for a saturated temperature equal to 1.85 K and a nominal heat load of the order of 247 W. For the ultimate (1.5 time the nominal) the measurement show less than 50 mK for 1.915 K and 315 W. Analysis and critique of our measurements were possible with a more consequent studies performed both at Fermilab and at CERN. The first observations show that the heat exchanger performances are very good.

The data were analyzed and upgrading of the test bench is in-process at CERN, in order to implement a direct measurement of the saturated temperature in the turnaround and feed-box side (temperature drop due to pressure drop). Extensive analysis remains to be done at Fermilab and at CERN in order to complete the full characterization of the LHC IRQ cooling system.

## **8 ADDITIONAL INFORMATION**

### **8.1 MULTI-LAYER INSULATION INVESTIGATION (MLI)**

This stay was also interesting to learn more on the evolution of projects that we used to develop some years ago. More tests were performed to measure the performance of the MLI between 77 and 1.9 K (Cryolab team: Giovana Vandoni, Jean-Michel Rieubland, Leatitia Dufet). The Cryostat Thermal Model became the Cryolab Long Test Facility. Its length is increased from 10 to 15 meters. The purpose of the CLTF is to measure the thermal performance of the MLI used for the LHC dipoles as well as the beam screen thermal performance.

The principle of measurement was completely renewed caused by the leakage problem that we met 2 years ago. Now, they use Kapitza measurement instead of boil off measurement at 1.9 K. We had a meeting with Giovana Vandoni, who introduced the status of their studies.

The concept of blankets has improved and takes into account our previous results. Tancrede Renault, from Jehier co. came to visit us. We took the opportunity to be at CERN to introduce to him the request for the LHC IRQ cryostat prototype out of the specification that we finalized at Fermilab before our departure. We gave him some raw estimation of the requested lengths and one week later he faxed us a quote. The bid is still on-going at Fermilab, including some more companies name (Austria Aerospace) that we were named by Lars Nielsen and Alain Poncet.

## **8.2 HEAT EXCHANGER TUBE INVESTIGATION**

Prior to the operation of the US-IT-HXTU, we had some contacts with Kabelmetal in order to plan a potential redesign of the heat exchanger tube in case of none adequate performance. Germana Riddone and Serge Claudet gave us interesting information regarding contact persons and the material data for a corrugated tube investigation.

The measurement performed on the SSHX proved the improvement due to the adequate surface treatment. Therefore we investigated the fabrication and storage of any potential treated copper corrugated tube. Antonio Perin told us about the nitrogen and argon atmosphere for the storage of RF cavities and other experiences.

Based on our current results of the US-IT-HXTU, such redesign is abandoned.

## **8.3 MAGNETS TESTS**

The proximity of the magnet test benches gave us the opportunity to learn more on their test results and the magnetic measurement difficulties for the LHC main quadrupoles and dipoles. The LHC/MMS activities went on in parallel with our tests. MBP2N2 and the SSS4 from Noell and Saclay were tested by August. The training consists in a series of magnetic tests when magnets are energized up to they quenched. Quenches are performed at 1.8 K and 4.2 K. In addition thermal cycles complete their training. These cold test benches did not consume more than 2\*3 g/s whereas we needed up to 315 Watt out of the CCU capacity.

## **Trip Report**

### **LHC IRQ Collaboration US-IT-HXTU Installation**

#### **List of contact**

June 12 – August 3, 2000  
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Knoops, Sigrid	CERN
Lamboy, Jean-Paul	CERN
Serio, Luigi	CERN
Tovar-Gonzalez, Antonio	CERN
van Weelderen, Rob	CERN
Vullierme, Bruno	CERN
<b>Survey</b>	
Beauquis, Bernard	CERN
Dobers, Tobias	CERN
Missiaen, Dominique	CERN
Quesnel, Jean-Pierre	CERN

<b>Electrical and powering</b>	
Bernal, Jean-Mathieu	CERN
Condemine, Michel	CERN
Guillaume, Claude	CERN
Pelletier, Sebastien	CERN
Vauthier, Nicolas	CERN
Woilet, Paul	CERN
<b>DAQ and control</b>	
Bart, Jean-Baptiste	CERN
Blanco, Enrique	CERN
Casas, Juan	CERN
<b>Vacuum Installation and Leak Check</b>	
Berthelier, Christian	CERN
Bochaton, Gerard	CERN
Gautier, Michel	CERN
<b>Safety Issues</b>	
Cheval, Cedric	CERN
Ravier, Gabriel	CERN
Vuillermet, Raphael	CERN
Margaroli, Claude	CERN
<b>Planning</b>	
Bonal, Pierre	CERN
Polaillon, Jean	CERN
Siemko, Andrzej	CERN
<b>General information</b>	
Bottura, Luca	CERN
Claudet, Serge	CERN
Erdt, Wolfgang	CERN
Lebrun, Philippe	CERN
Gerth, Dieter	KABELMETAL
Nicol, Tom	FNAL
Nielsen, Lars	CERN
Perin, Antonio	CERN
Pillet	BALZERS
Poncet, Alain	CERN
Riddone, Germana	CERN
Tavian, Laurent	CERN

## **Trip Report**

### **LHC IRQ Collaboration US-IT-HXTU Installation**

#### **Itinerary**

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FNAL  
August 25, 2000

CERN/ACR, Geneva Switzerland,  
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August 25<sup>th</sup>, 2000